Introduction

Steel Structures

Steel structures are metal structures made of structural steel components which are connected to bear the applied load and transfer safely to the ground. Steel structures are commonly used in various application such as construction of commercial building, bridges, warehouses due to their high strength. They are used to attain high tensile strength, durability etc.

Types of rolled sections

1. I sections: I sections are the universal steel sections having I shapes cross sections. They consist of two flange and one web.
2. H sections: H sections are the steel sections having H shaped cross section. They are similar to I section but have larger flange.
3. T Sections: T section are the steel sections having T shaped cross sections. T section consist of only one flange and a web.
4. Rolled round bars: Rolled round bars are the bars having circular cross section.
5. Rolled square bars: Rolled square bars are the bars having square cross sections.
6. Rolled channel section: The rolled channel sections are the section having C shaped cross sections.

Advantages of Steel Structures

- Steel structures are capable of withstanding heavy loads and impacts.
- Steel structures resist deformation, cracking and warping.
- Steel structures require minimal maintenance.
- Steel structure have a long life-span.
- Steel structure can be easily assembled and erected.
- Steel structures are fire resistive.
- They have high earthquake resistance property.
- Steel Structure can be easily modified and expanded.
- Steel are easy to transport.
- They can withstand ductile failure.
- Steel structures have high scrap value.

Disadvantages

- Steel structures need heavy initial investment.
- Steel structures are corrosive when exposed in weather.
- They do not insulate heat and cold.
- Skilled persons are required to erect.
- Complex design require additional support.
- They transmit noise and vibrations easily.
- Coating is required to prevent rusting.

Types of load on steel structures

- **Dead Load** (Dl) Dead load is defined as the self weight of structures and any permanent fixtures such as floor, walls, roofs etc.
- **Live load**: Live load refers to the variable loads imposed on the structure by the occupancy, furniture, equipment's and any other temporary objects.
- **Wind Load**: Wind load refers to the load of snow or ice accumulated on roofs and other horizontal structural parts.
- **Seismic Loads**: It refers to the load acting on a structure due to motion generated by seismic hazards such as earthquakes.
- **Dynamic loads:** Dynamic loads refers to the load acting on a steel structure due to moving objects, machinery vibrations, human activities etc.

Methods of Analysis

- **Elastic Analysis** :Elastic Analysis of steel structures is mentioned in IS800, clause 4.4. According to this method, all the members are assumed to remain elastic under the action of factored design loads for all limit states.

- **Plastic Analysis** : Mentioned in IS800, clause 4.5. According to this analysis the yield stress of the grade of steel shall not exceed 450MPa and the member shall be hot rolled.

Method of Design

- Working Stress Design: This method of design id mentioned in IS 800 Section 11
- **Plastic Design** :This method of design of steel structure focuses on utilizing full plastic capacity of member. This design method is based on the concept of plasticity, where the material undergo deformation without failure.
- Limit State Design IS 800 IS based on limit state design method. Limit state design is a modern approach to structural design that focuses on ensuring safety and serviceability of structures under various limit state.

Working Stress Method

Assumptions for WSM

- Plane section remains plain even after bending.
- Steel behaves as linear elastic material.
- The strain stress relation of steel is straight line under working load.
- The Modulas of Elasticity of steel is always constant
- The steel is homogeneous and isotropic through out the length.
- The structural member do not fail due to buckling load.
- Factor of safety to the structure to ensure that the structure can withstand the anticipated load.
- The method is suitable for structure subjected to static loads

Service Load

Service load are the loads that the structure is expected to experience during its normal use over its design life. It includes loads like dead load, live load, wind load, snow load etc.

Permissible Stress:

Permissible stress are the stress level at which the steel structural element can work safely. It is also

known as design stress or allowable stress. Mathematically it is the ratio of ultimate stress or yield stress to the factor of safety.

$$Permissible\ stress = \frac{Ultimate\ Stress}{factor\ of\ safety}$$

Limit State Method

Different Limit States

- **Limit state of strength**
    i. **Yielding**: Limit state of yielding occurs when max stress is applied that exceeds yield strength of material.
    ii. **Rupture**: Limit state of rupture occurs when the applied stress exceeds ultimate tensile strength of material.
    iii. **Buckling**: This occurs when the slender member fails due to lateral instability. Only occurs in compressive member.

- **Limit state of Serviceability**
    i. **Deflection**: Deflection occurs in a structural member due to simple loading. Mainly occurs in Beam.
    ii. **Cracking**: Cracking occurs in steel components due to excessive load or fatigue.
    iii. **Vibration**: Vibration occurs in structure due to vibrating elements such as machines, seismic loads, earthquake etc.

Design Strength

The design strength of material refers to the max stress

or force that a structural member can safely withstand without undergoing failure under design condition .For steel structure the design strength depends upon the yield strength or ultimate strength as well as grade of steel components. For limit state of design, the design strength is determined based on load factor.

Design Load:

Design loads refers to the expected load that a steel structure will experience during its design life. These load include dead load, live load, snow and wind load, dynamic load etc.

Joints in Steel Structures

Limit State of Failure in Riveted or bolted joints.

The limit state of failure of riveted or bolted joints refers to the condition at which the joint can no longer support the applied loads. The several limit state of failure are;

1. **Shear Failure** : Shear failure of a bolt occurs when the applied shear stress exceeds the strength of the bolt, causing it to fracture along the perpendicular to the applied loads.
2. **Tension Failure**: Tensile failure occurs when the applied tensile load exceeds the tensile strength of the bolt, causing it to fracture along its axis
3. **Bearing Failure** : Bearing failure of a bolt occurs when the connected parts deform locally under the bolt's head or nuts, leading to excessive bearing stress. Generally it doesn't occur for high strength steel and bolts.
4. **Tearing Failure of Plates** : It refers to the situation where the plates fails due to excessive tensile stress induced by applied load which leads to fracture or tearing of the material.

Welded Joints

Welded joints are the connection between two or more piece of metals formed by welding. Welding is the process which involves melting of metals at the joints and allowing them to cool down to create a strong bond.

Types

1. **Fillet weld joints:** A fillet weld joint is defined as the joint in which two members are joined together by welding at an approximately right angle to another one. A fillet weld can be concave, convex, mitre type.
2. **Butt Joints** : Butt joint is defined as the joint in which two steel members are taken closer at end to end and connected in a same plane together by welding process. This is the most common type of weld which is mostly used in piping systems. It is also known as groove weld joint.
3. **Slot and plug weld joint** : Slot and plug weld joint is the type of joint in which a hole is made in one of the metal piece and another piece is placed on top of it. The hole is then filled with weld metal, effectively joining the two piece of metals.

Efficiency of joint :

The connection components including bolts, plates and fasteners should possess sufficient strength and stiffness to withstand the expected loads without

failure or excessive deflection. The efficiency of a bolted connection refers to its ability to transfer loads effectively while maintaining structural integrity and minimizing the risk of failure. Mathematically, efficiency of bolted joint (η) is the ratio of strength of bolted joint to the strength of solid plate expressed in percentage. Efficiency represents the effectiveness of a particular bolted joint in any structural member.

Advantages of welded joints

i. The welding can be done quickly than riveted joint.
ii. It has better rigidity as compared to riveted and bolted joint.
iii. It has better appearance.
iv. It can be adopted for complicated structures.
v. It has more efficiency then riveted and bolted joints. vi. It is more economical.
vi. There is no need to provide holes for welded joints.
vii. The weight of member gets reduced.
viii. No need of bolts and rivets

Disadvantages

i. The welded joints are likely to distort due to uneven heating.
ii. There is more possibility of brittle failure.
iii. The inspection of welded joint is difficult.

iv. More skilled and experienced man power is required.
v. Maintenance cos is high for welded joints.
vi. More equipment’s are required to make the welded joints.
vii. It requires electricity.

Design of Tension Members

Types of Tension Members

1. **Wires and Cables :**Cables are the flexible tension members typically used in suspension bridge and cable bridge.
2. **Rods or Bars:** Rods are the square or round shaped tension members . These bars are threaded at the end and used with nuts. Bars and Rods are often used for bracing systems as sag rod to support purlins between trusses to support girts.
3. **Chains** : Chains are the tension members composed of interconnected links. Chains are mainly used in tension members for providing flexibilities.
4. **Built Up Tension Members**: Built up members are the members made by forming a connection between two or more standard members.

Net Sectional Area

Net sectional area of a tension member refers to the effective cross sectional area of the member that is available to resist tensile force. Mathematically it is gross cross sectional area minus total sectional area of holes. The net sectional area excludes area of holes, notches, or other discontinuities which can weaken the member.

$A_{net} = A_{gross}$ - Sectional Areas of holes

Tension Members

Tension Splices If the available length of single member is not sufficient for tension member, member are spliced from one piece to another to transfer applied tension. Tension splices are used in construction to join to structural tension members such as cables, rods etc. They are designed to efficiently transfer loads between the member and maintain their strength.

Lug Angles

When the tension member are heavily loaded, the length required for welding or number of bolts required is large. In such condition additional angle section is used to reduce the length and number of connection. The use of lug angles is to reduce the gusset plate The effective connection of lug angle shall as far as possible terminate at the end of member The connection of lug angle to the main member shall preferably start in advance to the member to the gusset plate.

Axially Loaded Compressive Member-Tubular and Angle Section

Axially Loaded Compressive Members

A compressive member refers to the structural element designed to resist axial compressive force. These members are typically used as columns, struts, trusses etc. Compressive members are specially designed to withstand buckling. Buckling is the vertical deflection due to excessive axial compression.

Types

1. **Columns**: Columns are vertical compression members that support load by resisting axial compression . There are two types of columns.
   i. If the slenderness ratio of the column is less than or equal to 12, then the column is known as short columns.
   ii. If the slenderness ratio of the column is greater than 12, then the column is known as short column.
2. **Struts**: Struts are the inclined compressive members that are used to support beams, truss.
3. **Piers**: Piers are vertical compressive members which are used in bridges to equally transfer the imposed load on earth.
4. **Rigid Frames**: Rigid frames are the structural member of non-load bearing structure composed of beams and columns.

End Condition

The way of securing the ends of vertical compression members is known as end condition or end connection. It is the support condition that determines the deflected shape of the member when load is applied to the member. The end condition may be free or restrained for rotation. If the end condition is free, then the end is free to rotate and translate. If the end condition is hinged, then the end is free to rotate but restrained against translation. If the end condition is fixed, then the end is restrained against both translation and rotation.

Effective Length

The effective length of an axial compression member is defined as the length of the column, which takes part in buckling when the member is subjected to axial compressive load. Effective length is the length between the points of contra-flexure of buckled column. The effective length of column entirely depends upon

i. End Condition
ii. Number of elements Member Interconnection
iii. Number of Joints

Radius of gyration

Radius of gyration is the property of the structural member that describes the distribution of cross-sectional area about its axis. It is commonly denoted by the symbol 'r' and is defined as the

square root of the ratio of the moment of inertia of the member about a given axis to its cross-sectional area. Mathematically, the radius of gyration (r) is expressed as:

$$r = \sqrt{\frac{I}{a}}$$

Where, I is second moment of inertia and a is the cross sectional area

Slenderness ratio

The tendency of member to buckle is usually measured by its slenderness ratio. Slenderness ratio of a section is the ratio of the effective length of the member to the appropriate radius of gyration. When the slenderness ratio is low (short members), the compressive load can be resisted primarily by material strength, and buckling is less likely to occur. However, as the slenderness ratio increases (long members), the influence of geometric imperfections and buckling becomes more significant, and the member is more susceptible to buckling under compressive loads. Mathematically slenderness ratio is given by:

$$Slenderness\ Ratio(\lambda) = \frac{Kl}{r}$$

Where K is an effective length factor and l is length of column as described previously.

Strength of Compressive Member

The strength of compressive member refers to ability to resist axial compressive load without undergoing failure. The strength depends upon the various factors such as materials property, cross sectional geometry, end conditions etc.

Flexural Members

Flexural Members refers to the structural element which are subjected to transverse loading. The length of the flexural member is comparatively large as compared to their cross section. Flexural members are provided in a building to support roof, slab, truss etc. Examples of flexural members are purlin, girder, joist. T beams, I beam, L beams, Closed section beams are the types of flexural member.

Roof Truss

Roof truss are the structural members which are provided to support the roof of a building. They consist of interconnected members arranged in triangular shapes to form sloped rigid structure.

i. **King Post Truss** :King Post Truss is a simple truss design consisting of a vertical central post with two inclined rafters and horizontal tie beam.

ii. **Queen Post Truss**: Queen post truss is similar to king post truss, but with two vertical posts instead of one.

iii. **Howe truss**: Howe truss is the type of truss having structural components connected in series. This truss can bear heavy loads and suitable for larger spans.

iv. **Fink Truss** : It is a truss having structural component characterized by a W-shaped pattern.

v. **Pratt Truss** :It is a truss design with diagonal members sloping towards center.

Components of Roof Truss

i. **Top Chord**: Top chords are uppermost rafters starting from one end of support to another end.

ii. **Struts**: These are the vertical or inclined members connected to the rafters and tie beam. The central strut is known as king post.

iii. **Pitch of truss**: It is the ratio of height of truss to its span.

iv. **Purlins**: Purlins are the large structural members which provide support to the rafters and GI sheets.

v. **King Post**: King post is the central strut of the truss which generally provides support to the apex of the truss.

vi. **Support**: Supports are the structures at the end of the truss in which the truss rests. The various types of loads acting on roof truss are live load, wind load, load of GI covering, Snow Load, seismic loads etc.

Tubular Sections

Tubular Sections ate the structural sections have hollow inside. The tubular section may be of various shapes like circular, square, rectangular etc.

- They have a high radius of gyration-They have high buckling strength.
- They have less self-weight.
- They have greater torsional resistance.

Timber Structures

Timber Structure

Timber is a natural versatile material which is obtained from trees and used in various applications ranging from construction of furniture products to structural members like beams, struts, truss etc. Timber can be obtained from exogeneous trees(grow outward in transverse) and endogenous trees(grow inward in longitudinal).

Requirements of good timber

- It should have a uniform color.
- It should have regular annual rings.
- It should give a clear sound when struck.
- It should be well seasoned.
- It should be free from natural defects.
- It should not be affected by fungi or termite.
- It should be hard, durable, and tough.
- It should not split when nail is driven into it.
- It should be freshly cut.

Properties of timber

- **Appearance:** Timber has a good appearance and is available in various colors/ textures and grain pattern.
- **Strength**: Timber free from defects are relatively strong which may bear a heavy load.

- **Durability** : Properly seasoned and preserved timber has high durability/ resistance against decay.
- **Insulation** : Timber offers natural insulation against heat/ cold and sound making it ideal for building construction.
- **Sustainability** :Timber is a renewable resource and is an environmentally friendly building material.
- **Workability** : Timber is easy to work with using simple tools and techniques. It can be easily sawn, drilled, shaped.

Factors affecting Timber Structure

- Species: Different tree species having varying levels of strength and durability.
- Moisture Content: The presence of moisture in timber decreases its strength. Moisture content leads to warping and decaying of timber.
- Grain: Timber with grain in longitudinal direction is stronger than grain along radial direction.
- Knots and defects: Knots, irregularities, and defects in the wood such as cracks splits can weaken timber and reduce the load bearing capacity.
- Cross section: Timber with higher cross section have greater strength against bending and twisting.
- Density: Higher density wood generally provides greater strength and stiffness.
- Treatment: Timber treatment and preservation such as pressure treatment, painting coating can enhance strength and durability.

Advantages of Timber Structure

- Timber is a renewable source.
- It can be recycled.
- The timber structure has a good appearance.
- Timber free from defects has high strength.
- It is easily workable.
- Timber structure has less dead load.
- Timber structure can insulate heat and cold effectively.
- It is a bad conductor of electricity when it is in dry condition.
- Timber structures are resistant against chemical reactions.

Disadvantages

- It can't bear heavy loads.
- It has low cross-sectional area.
- It gets easily affected by moisture.
- It is not fire resistive.
- It gets easily affected by fungi termites etc.
- Timber structures have limited design flexibility.
- Timber structures require high maintenance.
- Timber structures have limited span capacity.
- They have less dimensional stability.

Types of timber joints

- **Butt Joint**: Butt joint is the most fundamental joint, in which two distinct wood pieces are placed side by side.

- **Miter Joint**: Miter joint is the type of joint in which two pieces are cut at 45 degrees jointed to make 90-degree angle.
- **Lap joint**: Lap joint is the type of joint in which two wooden pieces are overlapped at end.
- **Tongue and groove joint**: Type of joint in which one wooden piece is cut as tongue and another one is cut as groove to create greater strength connection.